P-3.1 Apply energy formulas to determine potential and kinetic energy and explain the transformation from one to the other

Revised Taxonomy Levels **3.2 C_A Apply (implement) procedural knowledge**
2.7 B Explain conceptual knowledge

Key Concepts
Potential energy
Kinetic energy
Mechanical energy
Conservation of energy
In physical science students "explain the factors that determine potential and kinetic energy and the transformation of one to the other" (PS-6.). They do not address the formulas for potential and kinetic energy or the mathematical aspect of the transformation, one to the other.

It is essential for students to
- Analyze potential energy (energy of position) and kinetic energy (energy of motion) using energy formulas
- Understand that the gravitational potential energy of an object is equal to the object's weight (mass x acceleration of gravity) multiplied by the vertical distance through which the object is lifted. ($E_p = ma_gh$) = (N)(m)
- Understand that the kinetic energy of a moving object is equal to the object's mass times its velocity-squared, divided by two. ($E_k = ½ mv^2$) = Nm
- Understand that the unit used to measure energy is the joule (Nm)
- Understand that the potential energy of an object can be converted to kinetic energy or the kinetic energy to potential energy.
- Solve problems involving transformations between potential and kinetic energy.

Assessment
The verb implement (apply) means that a major focus of assessment should be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure is application of the concept of the conservation of energy during transformations between kinetic and potential energy. The unfamiliar task should be a novel word problem or laboratory investigation. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of each of energy conservation as well as mastery of the skills required to implement the mathematical equations or in order to solve problems.

The verb explain means that another focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how the energy is conserved during kinetic-potential transformations.
Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how a change in one type of energy affects the other type of energy.

P-3.2 Apply the law of conservation of energy to the transfer of mechanical energy through work.

Revised Taxonomy Levels 3.2 C_A Apply (implement) procedural knowledge
Key Concepts
Law of conservation of energy
Mechanical energy
work

In 6th grade, students recognize that "energy is the ability to do work"
In physical science students

- Explain how the law of conservation of energy applies to the transformation of various forms of energy (including mechanical energy, electrical energy, chemical energy, light energy, sound energy, and thermal energy).
- Explain work in terms of the relationship among the force applied to an object, the displacement of the object, and the energy transferred to the object (PS-6.3).
- Use the formula W = Fd to solve problems related to work done on an object. (PS-6.4) and that the unit for work is the joule (Newton-meter)
- Address the concept of work as a means of transferring energy from one system to another
- Physical science students have not addressed energy quantitatively so they have not addressed the units used to measure energy.

It is essential for students to

- Analyze the transfer of mechanical energy through work
- Solve problems showing that mechanical energy is conserved as it is transferred from one object to another through work

Assessment
The verb implement (apply) means that a major focus of assessment should be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure is application of the concept of the conservation of energy as it is transferred from one object to another through work. The unfamiliar task should be a novel word problem or laboratory investigation. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of each of energy conservation as well as mastery of the skills required to implement the mathematical equations or in order to solve problems.

P-3.3 Explain, both conceptually and quantitatively, how energy can transfer from one system to another (including work, power, and efficiency).

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge
Key Concepts
Work
Power
Efficiency

This concept is not addressed in physical science

It is essential for all students to
Apply and analyze the relationships among energy, work, power, and efficiency both conceptually and quantitatively in linear and rotational systems

- ❖ Understand that power is the rate of work, power = work/time
- ❖ Understand that the unit for linear power is the watt,

joule/sec
(Newton)(meter)/sec

	Linear Motion	**Rotary Motion**
	Force (F)	Torque (τ)
kinetic energy	$E_k = ½ mv^2$	$E_k = ½ m \omega^2$
work	$W = F\Delta d$	$W = \tau \Delta\theta$
Power	$P = W/t$ $P = F\Delta d/t$	$P = W/t$ $P = \tau \Delta\theta/t$
Efficiency	Efficiency = W_{output}/W_{input}	Efficiency = W_{output}/W_{input}

- ❖ Compare ideal and actual force transformers
- ❖ Apply force transformation formulas to calculate efficiency of rotational systems
- ❖ Explain how a wheel and axel transforms force
- ❖ Explain how belt-drivers, gear-drives and disk-drives use similar methods to achrive trade-offs between torque and speed

Assessment
The verb explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how the energy is conserved during transformations in terms of work, energy, power and efficiency. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how a each variable (work, energy, power, and efficiency) are involved in specific energy transformations.

P-3.4 Explain, both conceptually and quantitatively, the factors that influence periodic motion.

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Key concepts

Periodic motion

In physical science, students may discuss pendulums but only in terms of the transformation of kinetic and potential energy, not in terms of periodic motion

It is essential for students to

- Understand that when a body moves repeatedly over the same path in equal intervals of time, it is said to have periodic motion.
- Understand that "simple harmonic motion" is a type of periodic motion which has the following characteristics
  - It is linear motion
  - A continually changing net force is exerted on the object
    - The magnitude of the net force decreases as the object moves towards the point of equilibrium.
    - The magnitude of the net force increases as the object moves away from the point of equilibrium.
  - Because the net force is continually changing, the rate of acceleration is continually changing.
    - The rate of acceleration is proportional to the displacement from the equilibrium position
    - The rate of acceleration decreases as the object moves towards the point of equilibrium.
    - The rate of acceleration increases as the object moves away from the point of equilibrium.
  - As the object is accelerating, the speed of the object is continually changing.
    - As the object moves toward equilibrium, there is a decreasing net force acting on it in the direction of the equilibrium position.
    - The decreasing net force causes a decreasing acceleration
    - Even though the rate of acceleration is decreasing as the object moves towards equilibrium, the object is still accelerating the entire time that it is moving toward the equilibrium position.
    - So the object continually speeds up as it moves towards the equilibrium position
    - The speed of the object is at a maximum at the point of equilibrium
    - At the point of equilibrium, the direction of the net force changes
    - The new net force causes an acceleration, but this time in the direction opposite to the motion of the object
    - As the object moves past the equilibrium point, the net force causes the object to accelerate by slowing down.
    - The speed of the object is at a minimum when the object is at the points farthest from the equilibrium and at a maximum at the point of equilibrium
    - The speed of the object is inversely proportional to the displacement from the equilibrium position

- ❖ Explain (both qualitatively and quantitatively) the motion of a pendulum and the motion of a weight hanging on a spring based on the principles of simple harmonic motion

Physics for the Technologies differentiation

- ❖ Explain the relationship between elastic potential energy and an object's position

Assessment

The verb explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how the motion of familiar objects in terms of simple harmonic motion

Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how each variable (force, acceleration and velocity) are involved in specific energy transformations.

P-3.5 Explain the factors involved in producing a change in momentum (including impulse and the law of conservation of momentum in both linear and rotary systems).

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge

Key concepts
Law of conservation of momentum
Rotary motion

Students did not address the principles of momentum in physical science

It is essential for students to
- Understand that momentum is the product of the mass of the moving body and its velocity.
  - the symbol for momentum is "p"
  - $p = mv$
- Understand that the momentum of an object can be changed by a force applied over time. The longer that a force is applied to an object, the more the momentum of an object will change.
  - The product of force and the time interval during which it acts ($F\Delta t$) is called impulse
  - Impulse = change in momentum
    $F\Delta t = m\Delta v$
- Explain rotational inertia
- Explain the law of conservation of momentum in linear and rotary systems.

Assessment
The verb explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how force exerted over time affects the momentum of familiar objects. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how each variable (force, and time) affect the motion of the object.